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CORNING GLASS WORKS
ELECTRO-OPTICS LABORATORY
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IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

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ABSTRACT

A new type of rear projection screen is discussed which promises very high resolution and has flexibility in optical properties comparable to glass-ceramic powder screens. Modulation transfer function data is presented for some selected Corning and commercial screens. The new Corning screens have a resolution limit greater than 100 cycles/mm.

The effects of absorbing material on screen performance are discussed, and it is shown that from modulation transfer function considerations the absorbing material should be distributed throughout the screen volume, while for maximum effectiveness in rejection of ambient light the absorbing material should be in the form of a thin layer on the screen surface.

TECHNICAL REPORT NO. 28

I. A New Rear Projection Screen

A. Description

A new type of rear projection screen, termed the discrete particle screen, is being developed. The screen consists of a thin scattering layer coated on a transparent substrate. The scattering layer is a clear plastic binder containing discrete metallic oxide scattering particles. These particles are available in average sizes ranging from 0.3 to 3.0 microns, therefore Mie scattering can be obtained. The refractive index of the particles is typically 1.65.

B. Comparison with Ceramic Powder Screens

There are some important similarities between discrete particle (DP) screens and ceramic powder (CP) screens. Mie scattering theory is applicable to both screen types. The particle size and concentration flexibility of CP screens is also obtainable with discrete particle screens, because a wide range of sizes of metallic oxide powder is available, and the concentration is controlled by the proportions of the binder-particle mixture from which the screens are made. The DP screens have some flexibility in the refractive index of the scattering particle as does the CP screen, in that available metallic oxide powders have different refractive indices.

A significant difference between DP and CP screens is that the CP scattering layer is a three-component system consisting of binder, bulk glass, and scattering centers; the refractive index of the binder and the bulk glass must be matched to prevent additional scattering at the glass-binder interfaces. However, the DP scattering layer is a two-component system consisting of the binder and metallic oxide scattering particles, and no index matching is required. Also, DP screens can be made much thinner than CP screens, because the CP layer thickness is limited to a size larger than the bulk powder particle diameter, while the DP layer thickness is limited only by the diameter of the scattering particles, and by the requirement that no light be specularly transmitted. This allows screens having very thin scattering layers to be made, and very high resolution screens result. DP screens have been made with layer thicknesses of less than 10 microns, which resolve square-bar patterns of space frequency greater than 100 cycles/mm.

Because of the above-mentioned advantages of DP screens over CP screens, we are concentrating our efforts on optimization of the DP screen during the remainder of the contract period.

II. Modulation Transfer Function Measurements

A. Results and Discussion

Modulation transfer function data has been obtained for several DP screens, and a sample of Polacoat LS60 has been remeasured. The resulting MTF curves are shown in Fig. 1. Data was taken at 5, 10, 20, and 50 cycles/mm. for all the screens except LS60. The LS60 MTF, which agrees well with an earlier measurement as reported in Technical Report No. 25, was linearly extrapolated after 20 cycles/mm, and there was no measurable contrast at 50 cycles/mm. Note that there is a "plateau" in the MTF curves for the DP screens, i.e. the MTF falls fairly rapidly at low-space frequency and then tends to level out.

DP110 and DP111 (see Fig. 1) were intended to be identical screens except for the absorbing material contained in DP110. The data indicates that the absorbing screen has a significantly greater MTF than the non-absorbing screen; however, subsequent investigation has shown that the increase in MTF of the DP110 screen is, for the most part, due to a decreased scattering layer thickness. (The effect of absorbing material on MTF is discussed in the next section).

The relatively low MTF values of DP101 result from multiple scattering caused by excessive particle number density. Multiple scattering is also present in DP110 and 111, but to a lesser degree. Additional screens are being fabricated having decreased particle number densities and thinner scattering layers, which should give significant improvement in MTF. We are investigating the effect of various screen parameters on MTF with the goal of fabricating screens which meet the contract requirements for MTF, keeping in mind the other requirements to be met.

B. Noise Averaging in MTF Measurements

The measurement of the MTF of rear projection screens is a particularly difficult task, primarily because of low light levels at the detector. For this reason a slit parallel to the spatial frequency pattern rather than a pinhole is used before the photomultiplier tube. This slit has the effect of averaging out the large fluctuations in the intensity parallel to the slit. These fluctuations are caused by the microstructure of the screen, which is one of the major factors contributing to the breaking up of the image at higher spatial frequencies. Thus the MTF values obtained are optimistic and would be expected to be different if measured using different MTF equipment. However, it is important to remember that because all samples are being measured using exactly the same techniques, the MTF data is a very good indicator of relative differences in resolving power.

III. Effects of Absorbing Material on Screen Performance

A. MTF Effects

The shape and extent of the modulation transfer function of a rear projection screen is determined by the shape of the single particle scattering function, the order of the scattering, and the thickness of the scattering layer. Let us assume a simple model for the contrast degradation mechanism in rear projection screens, namely that the degradation is caused by the lateral, or off-axis, propagation of light within the scattering layer. Then if the MTF values of a high gain and a low gain screen having the same scattering layer thickness are compared, the high gain screen will have the higher MTF values because there is less lateral light propagation in the high gain screen. This trend can be experimentally verified, which gives some weight to this simple model. The laterally propagated light is roughly analogous to cross-talk between adjacent optical communication channels.

Based on this model, any technique which reduces the amount of lateral light propagation should increase the MTF. Therefore, a screen in which the binding material is absorbing should have higher MTF values than a corresponding screen with no absorption. This effect was observed to some degree, as reported in Section II. Note that at high space frequencies the distance from a maximum to a minimum in the sinusoidal test pattern is very small, and consequently the effect of the absorber on MTF is minimized because the path length is not great enough to allow significant absorption of the laterally propagated light. Investigation of this problem is continuing.

B. Ambient Light Sensitivity Effects

In a typical rear projection screen which contains absorber in order to reduce the diffuse reflectance, the absorber is distributed throughout the screen volume, e.g. the binder resin may be dyed. In this configuration the ambient light which is back-scattered near the screen viewing surface is not attenuated as much as that part of the ambient light which is backscattered deep in the screen, because of the shorter path length involved, i.e. some of the ambient light is back-scattered before it suffers much attenuation by the absorber. A more effective configuration is one in which the absorbing material is in the form of a separate layer covering the viewing side of the screen. This requires that all the ambient light which strikes the screen and is diffusely reflected back to the viewer passes at least twice through the absorbing layer before it emerges from the screen. The result is that less absorber, i.e. less neutral density, is required to achieve a given diffuse reflectance, and this results in an increase in the efficiency T_{90}. Thus we see that from MTF considerations it is desirable that the absorber be distributed throughout the screen volume, while ambient light sensitivity indicates that a separate absorbing layer is preferable. The relative magnitudes of these effects and the desired optical properties will indicate what kinds of trade-offs should be made for a given application.

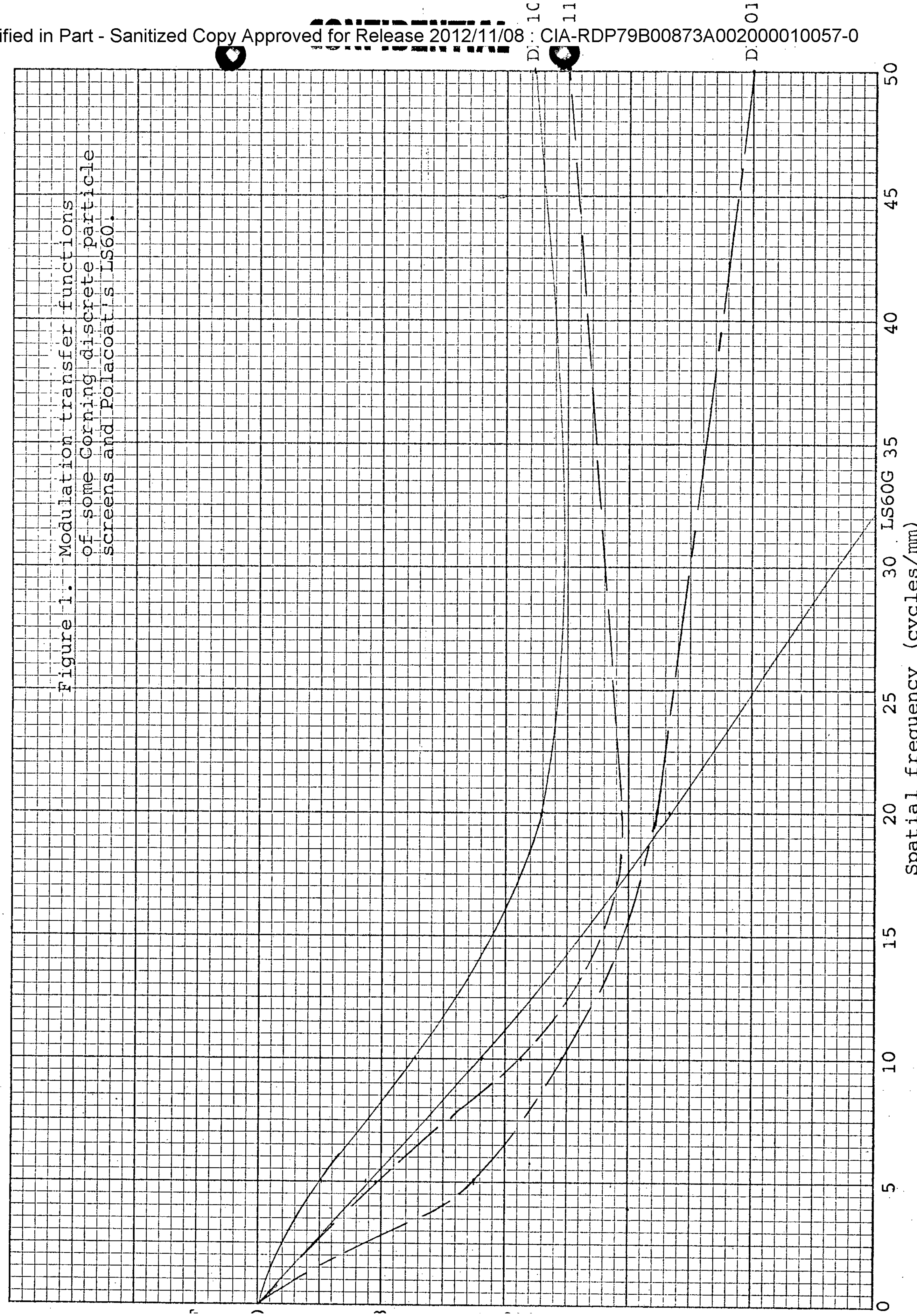

Figure 1. Modulation transfer functions of some Corning discrete particle screens and Polacoat's LS60.